NASA Procurement Lessons Learned

Glenn Butts

NASA

Kennedy Space Center

The source of knowledge is experience.

Experience is of two kinds-our own, & that of others.

Knowledge gained from our own experience is most expensive.

Mystery & ignorance are always coexistent.

Learn the truth & the mystery will disappear.

National Aeronautics & Space Administration

NASA's Constellation program – based largely on existing technologies – was based on a vision of returning astronauts back to the Moon by 2020.

However, ***the program was over budget, behind schedule***, & lacking in innovation due to a failure to invest in critical new technologies.

The President's Budget ***cancels Constellation*** & replaces it with a bold new approach that invests in the building blocks of a more capable approach to space.

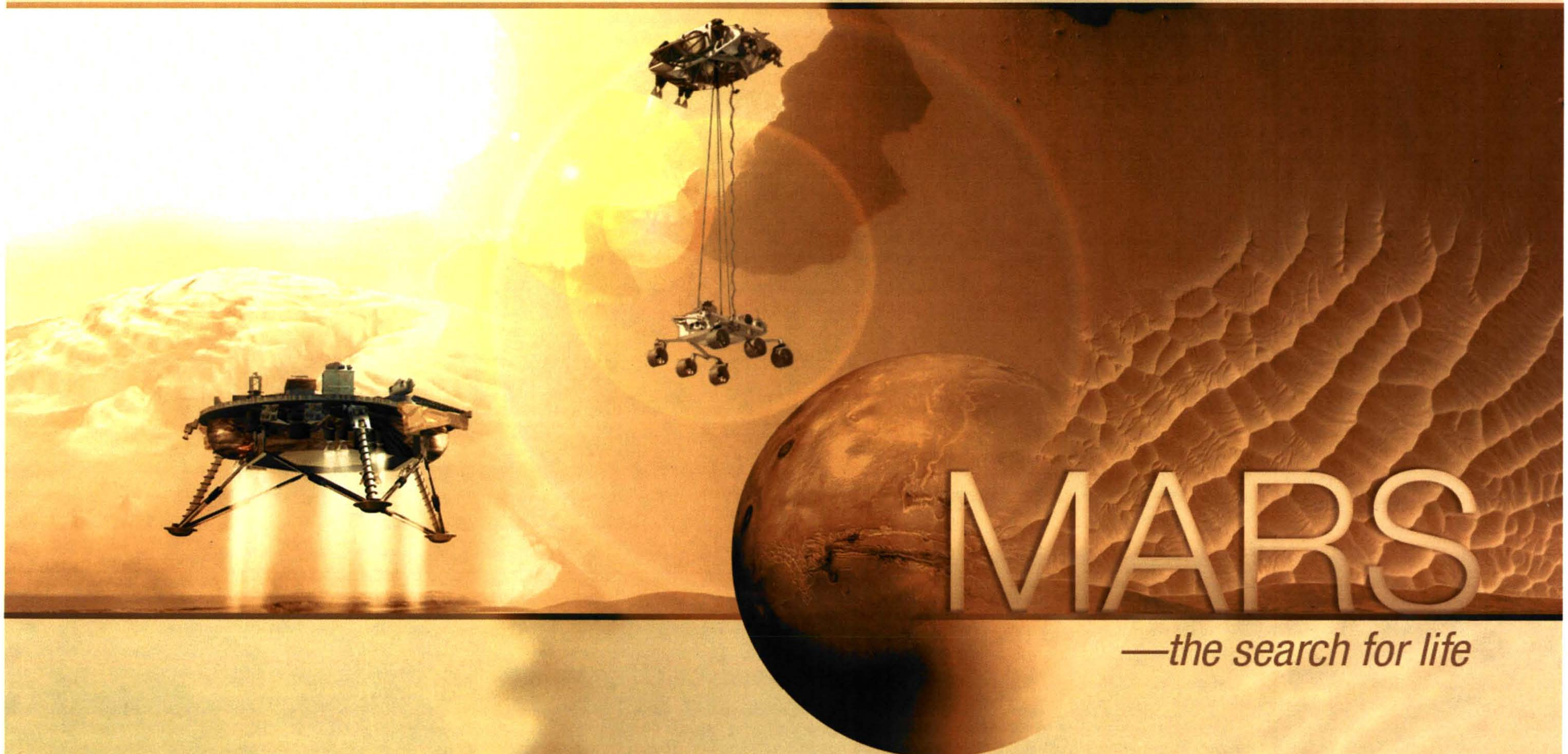
In the last 20 years NASA has spent at least $21B on canceled Space Transportation Programs

~7% of its Budget

Overruns can have real consequences

National Aeronautics and Space Administration

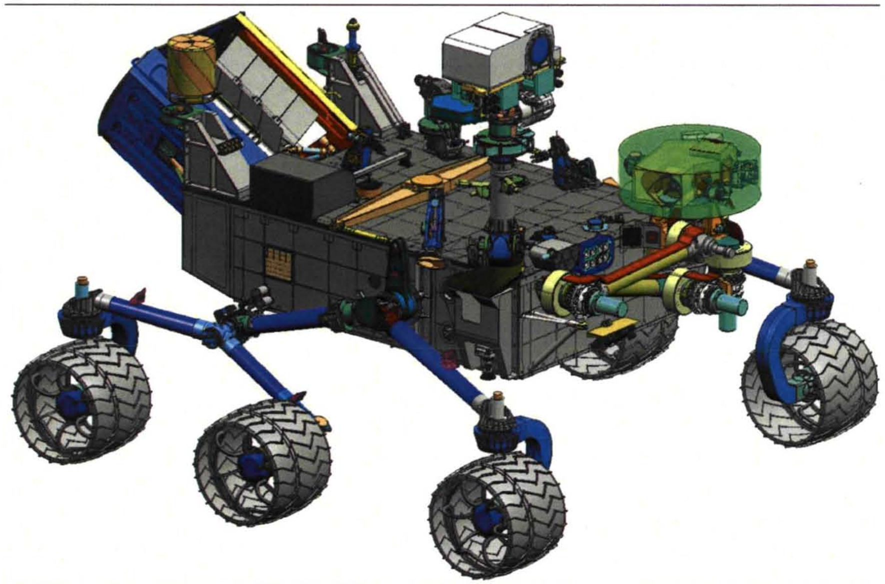
Mars Science Lab (MSL) Status



MSL Project Overview

Science
Focus on Past & Present Habitability of Mars
Highly Capable Analytical Laboratory
Next Generation Remote Sensing & Contact Investigations
Suite of Environmental Monitoring Instruments

Planned Launch: Oct-Dec 2011



Technical Capabilities
One Mars Year surface operational lifetime (669 sols/687 days)
Discovery Responsive over wide range of latitudes and altitudes
Precision Landing via Guided Entry
Skycrane Propulsive Landing
Long Distance Traverse Capability (20 km)
Flexible & Robust Sample Acquisition & Processing

MSL Growth Timeline

Legend:
KDP — $1,381M — 2005
Life Cycle Cost
Date of Review

Pre Phase A — $650M

Phase A	$1,381M	2005
SRR	$1,546M	12/2005
PDR	$1,645M	8/2006
CDR	$1,645M	6/2007

KDP accelerated up from Baseline

Rebaselines

Descope Review	$1,671M	8/2007
Re-Baseline	$1,886M	6/2008
Re-baseline	$2,031M	10/2008
Re-baseline	$2,271M	12/2008

Descope Review:
- One instrument Deleted & two instruments have descopes
- ~$27M in descopes in addition to cost increase

10/2007 AA reinstates Instrument Descopes

Re-Baseline 6/2008: ~$200M increase

Re-baseline 10/2008:
- ~$140M increase

Re-baseline 12/2008:
- ~$240M increase
- LRD delayed from 2009 to 2011

Rebaseline Review 06/2009

Cost: $2,394M

2011 Cost $2,470M

Current Launch date late 2011
Original plan to launch in 2009

MSL Finding #4

- Lack of quantitative evidence for findings provided at KDP & Rebaseline Reviews

Findings - Schedule

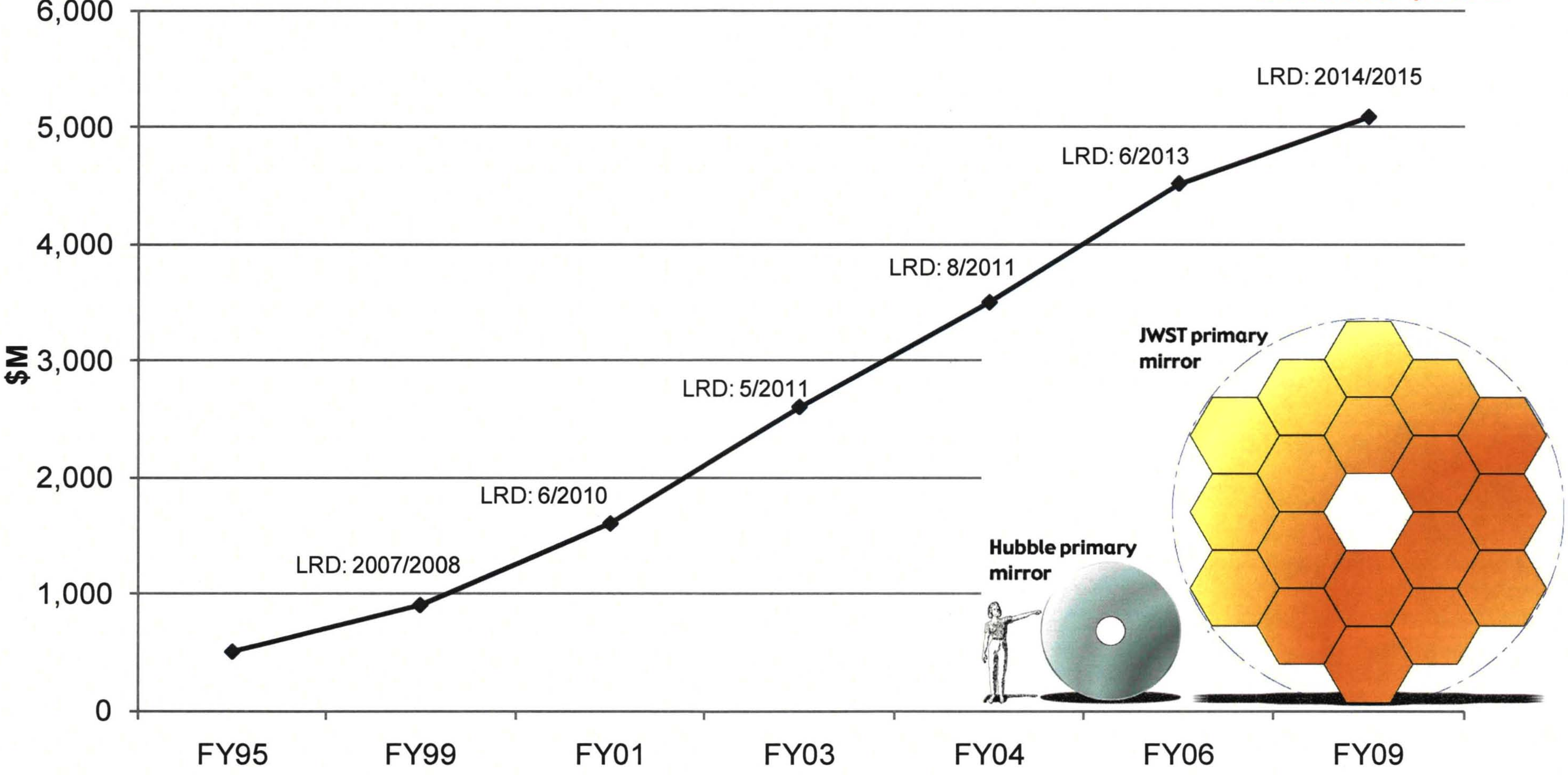
Mars Science Laboratory

- Schedule has healthy margins
  - 3 month early delivery to launch site part of the plan
  - Plan includes completion of all flight S/W builds before launch
  - 2 launch windows offer potential additional schedule relief (each has different implications for coverage during EDL)
    - Type II Oct 15-Nov 18, Type I Nov 25-Dec 18
  - Integrated cost/schedule risk analysis shows LRD at early opening of window has a 97% or better probability, assuming adequate and timely budget is made available
- Avionics system (including hardware and software), actuators, rover power system, SAM instrument represent a significant threat still
- Project evaluating options for ATLO flow. SRB believes that options beyond the baseline "option 2" add technical and programmatic risk

Same statement shown at both 6/2008 and 6/2009 Review

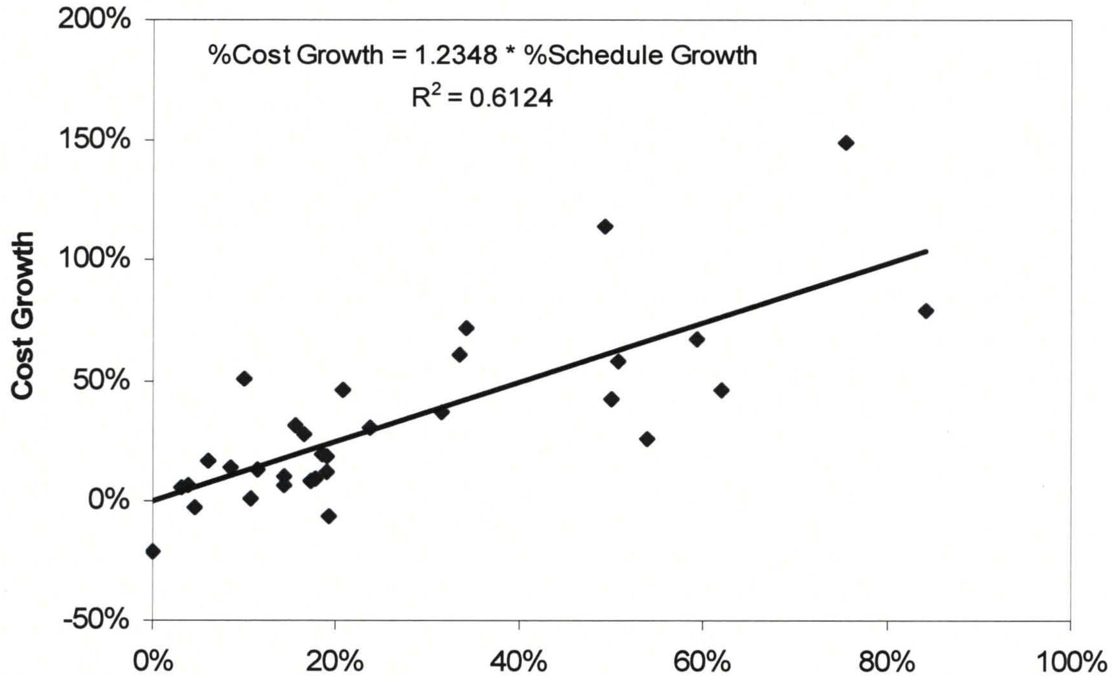
James Web Space Telescope (JWST) Cost & Schedule History

Current $6.5B



Current launch date rumored to be between 2018-2024

History on 40 Spacecraft Projects
Interrelationship of Cost and Schedule*



Interrelationship of Cost and Schedule Growth for Non-Restricted Launch Window Projects

Spacecraft Rule of Thumb: For every % Schedule Growth leads to equal or greater % of Cost Growth

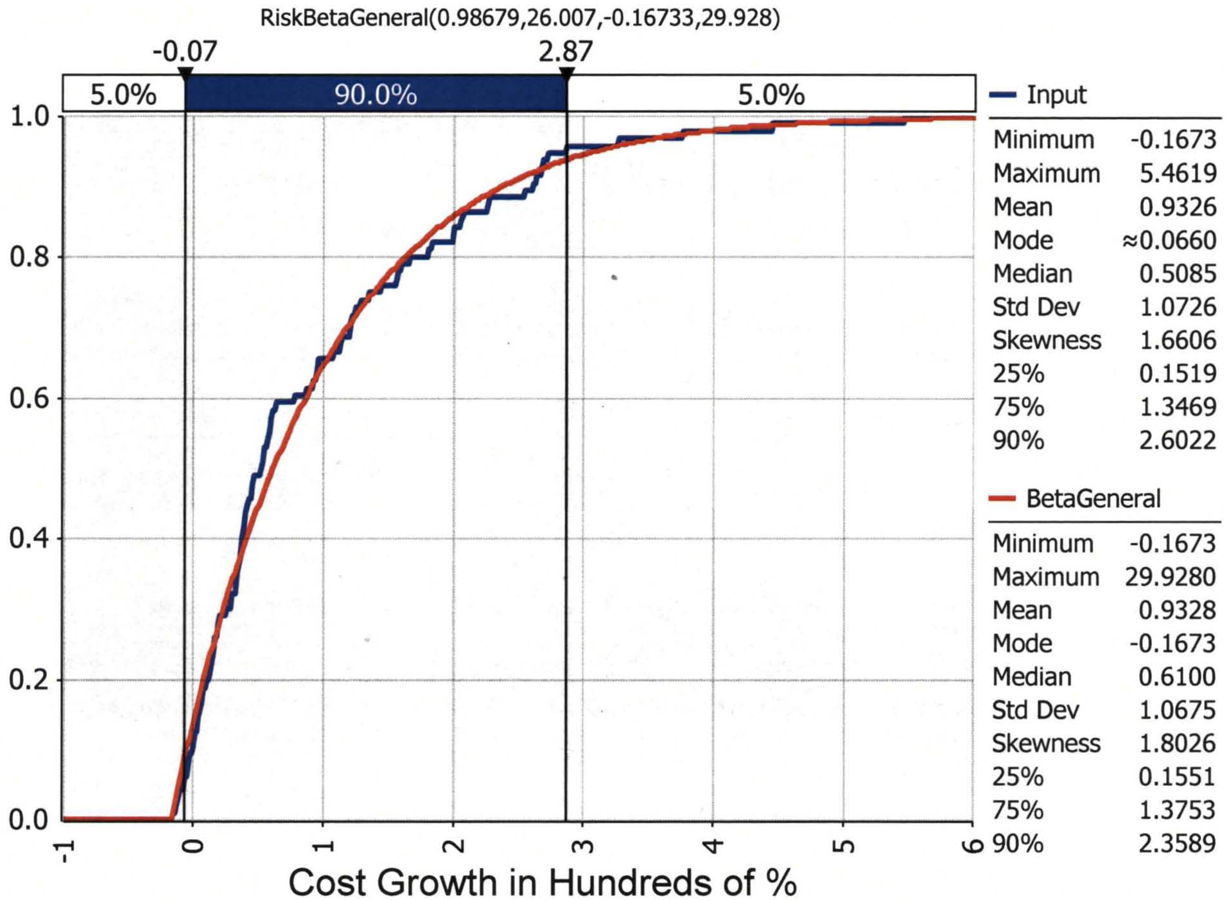
- Recent results from study of 40 NASA missions show correlation between cost & schedule growth
- The corresponding relationship states that for every 10 percent of schedule growth, there should be a corresponding 12 percent increase in cost growth.
- Although the variations can be significant, a general rule of thumb could be followed that states that for every percent of schedule growth, there will more than likely be an equal or greater percent of cost growth.

* Using Historical NASA Cost and Schedule Growth to Set Future Program and Project Reserve Guidelines Presented at the IEEE Aerospace Conference, March 3-10, 2007, Big Sky, Montana

History of 96 Spacecraft Projects

1st Available Cost Estimate to Last Available Cost Estimate

Data includes projects at various phases of development.



Only 12.5% chance of completing project on or under budget.

Average cost growth: 93% & Median: 51%

If overruns are consistent they can be predicted

Probably understated due to re-baselining & cancellation events.

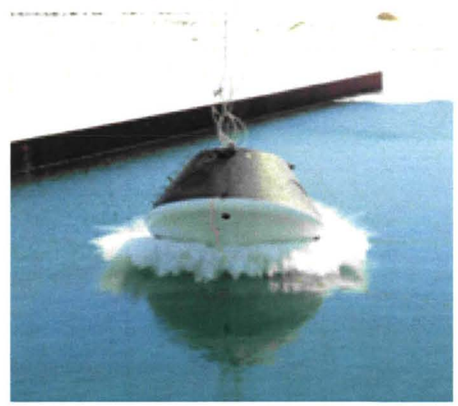
The project team protests....

"But these are spacecraft projects facilities are easier."

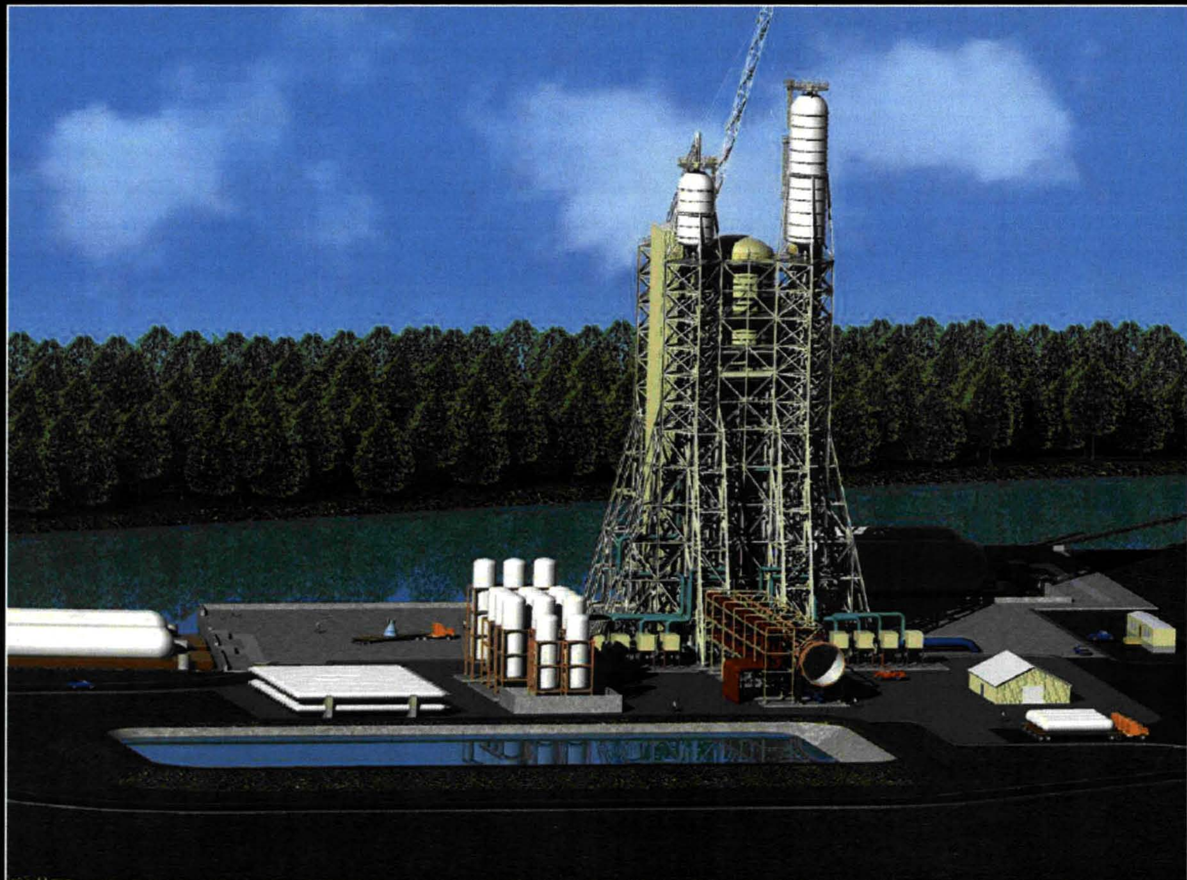
Recent Facility Cost and Schedule Growth

- ***A-3 Test Stand***
  - $157 M initial estimate
  - $320 M current project estimate
    - 2.04 times original
  - $366 M ICE estimate
  - *Latest available duration 7 years 1.75 times longer than original estimate*
- ***SET***
  - $ 63 M original estimate
  - $152 M latest available estimate
    - 2.41 times original estimate
  - *Latest available duration 7 years 1.75 times longer than original estimate*
- ***O&C IOZ***
  - $ 18 M original estimate
  - $55.2 M latest available estimate
  - $55.3 M ICE estimate
    - 3.07 time original estimate
  - *Construction Duration 18 months original - actual 27.3 months (1.52 times)*
- ***Hydro Impact Basin***
  - Conceptual Design Construction Cost Estimate: $1.89M
  - Final Design Construction Cost Estimate: $2.60M
  - Construction duration
    - 90 days estimate
    - 210 days reality
    - 2.33 times longer than original

Data suggests the larger the project the higher the cost growth



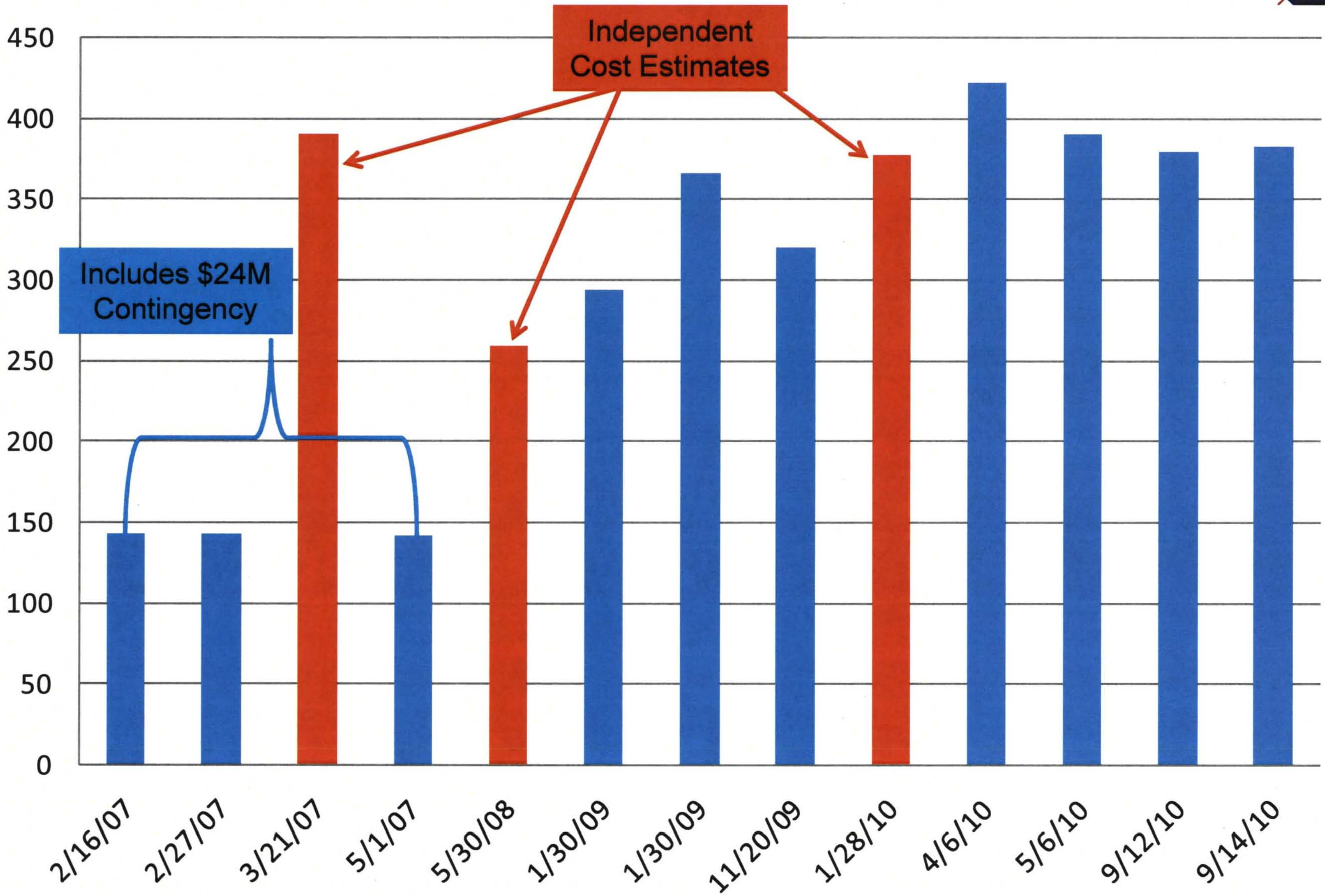
A-3 Test Stand



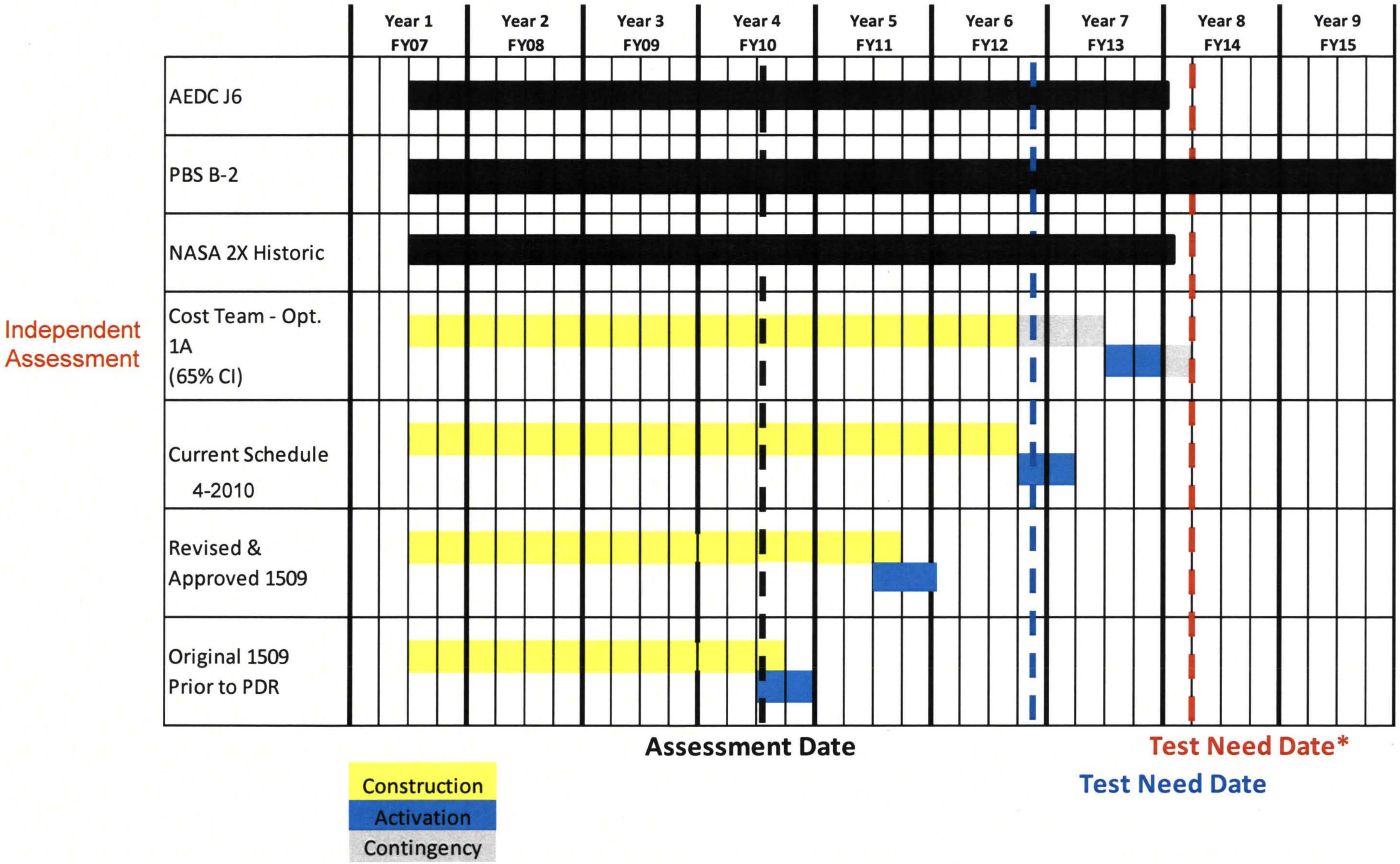
- •300 feet tall
- •Open steel frame structure
- •Up to 1 million pounds of thrust
- •Simulates altitudes up to 100,000 feet by generating steam to create a vacuum

The new A-3 Test Stand will allow engineers to test operating parameters of the J-2X engine for the Ares launch vehicles by simulating conditions at different altitudes.

A3 Cost History

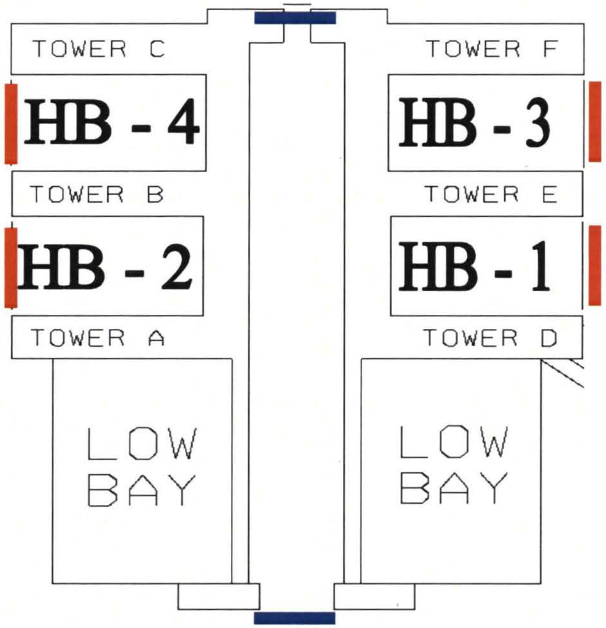


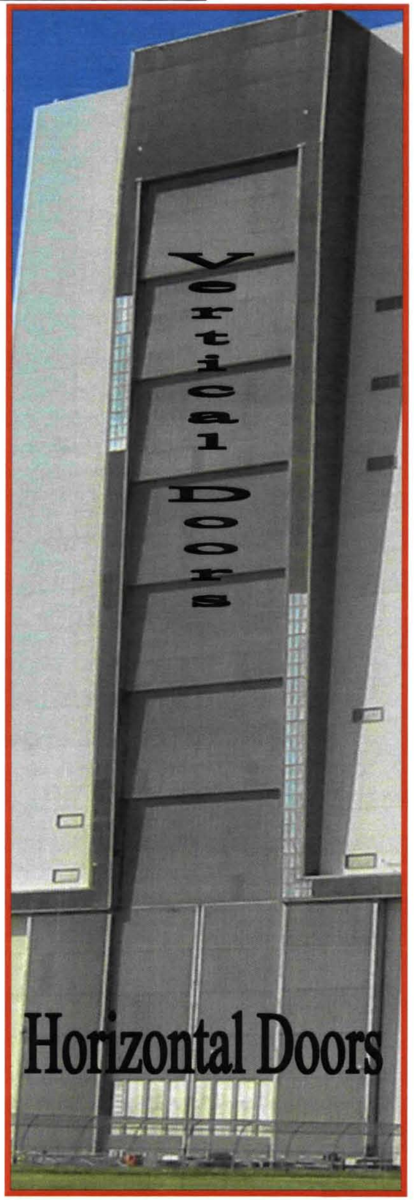
A3 - Schedule



Year 1 FY07
Year 2 FY08
Year 3 FY09
Year 4 FY10
Year 5 FY11
Year 6 FY12
Year 7 FY13
Year 8 FY14
Year 9 FY15
AEDC J6
PBS B-2
NASA 2X Historic
Independent Assessment
Cost Team - Opt. 1A (65% CI)
Current Schedule 4-2010
Revised & Approved 1509
Original 1509 Prior to PDR
Assessment Date
Test Need Date*
Test Need Date
Construction
Activation
Contingency

VAB Door Refurbishment
A Tale of Two Projects





- ½ building done cost plus
- ½ building done fixed price
- *Which one cost more?*

Transfer Aisle Doors

Other Recent Facility Projects
Cost and Schedule Growth

- **Cost Plus VAB Door Renovation**
  - $ 9.5 M original estimate
  - $56.5 M final cost
    - 5.95 times original estimate
- **Fixed Price VAB Door Renovation**
  - $27.0 M original estimate
  - $27.6 M final cost
    - 1.02 times original estimate

Essentially the same scope done by the same contractor

- **Cost Plus Processing Facility**
  - $135 M original estimate
    - $135M @ 60% design complete
    - $163M @ 90% design complete ± 5%
    - $180M @100% design complete
  - $370 M current estimate
    - 2.74 times original estimate
  - *Scheduled duration 8.6 years 1.75 times longer than original estimate*

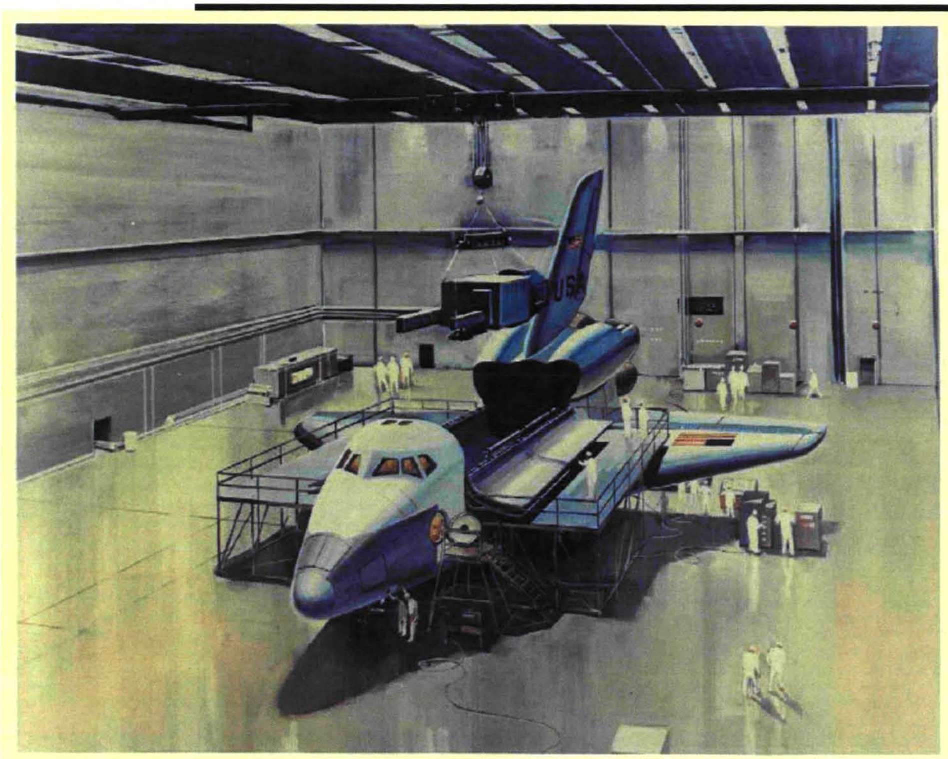
Ok there *may* be some risk....

What are the causes?

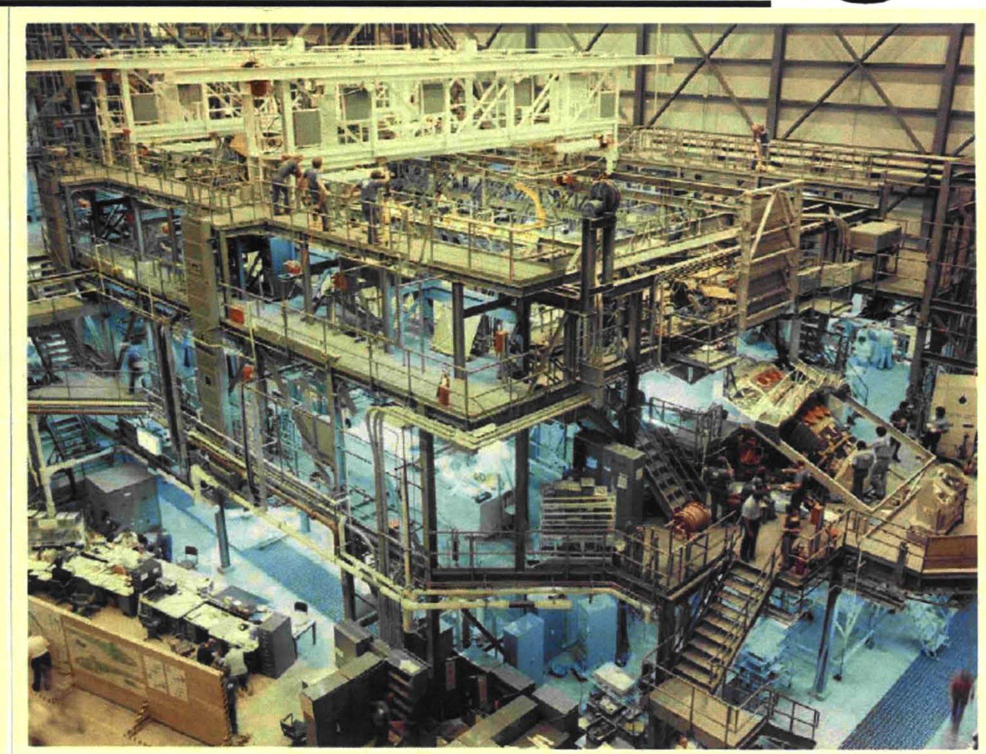
My Personal Assessment
Root Cause Analysis

1. **Deliberate lowball estimates & optimistic assumptions**
   - ***Often with management "encouragement" to get project approved***
   - Once approved, and billions are spent, it's difficult to cancel project
   - Projects repeatedly understate required reserves
     - Despite history of overruns
     - What is there is often transferred to other overrunning projects
     - When problems arise, money is "borrowed" from next task
     - Cash eventually runs out and, if more is not available, work gets delayed
     - Problems compound and project costs balloon
2. **Naïve**
   - Project optimistic about risks & ability to defeat technical challenges
     - Costs & schedules are based on best-case scenario and ignores risk impacts
   - Project always assume they will quickly overcome challenges
     - Problems that delay one task have ripple effect on next task, and the next one
       - Delays have associated cost impacts, such as keeping workers while awaiting resolution of big problems.
3. **Engineers want to build perfect systems**
   - Big difference in costs, and "good enough" is all that is required
     - Gets complex, and management cant or wont argue details
4. **Ignore/influence independent assessments**

Example of Assumption Problems



Shuttle Operations Concept 1974
What was estimated



OPF Today
What was built

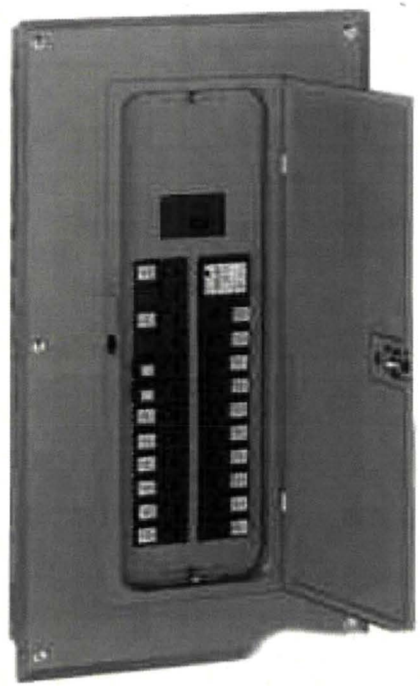
Bad Assumptions = Bad Estimates

But we are Smarter Now!

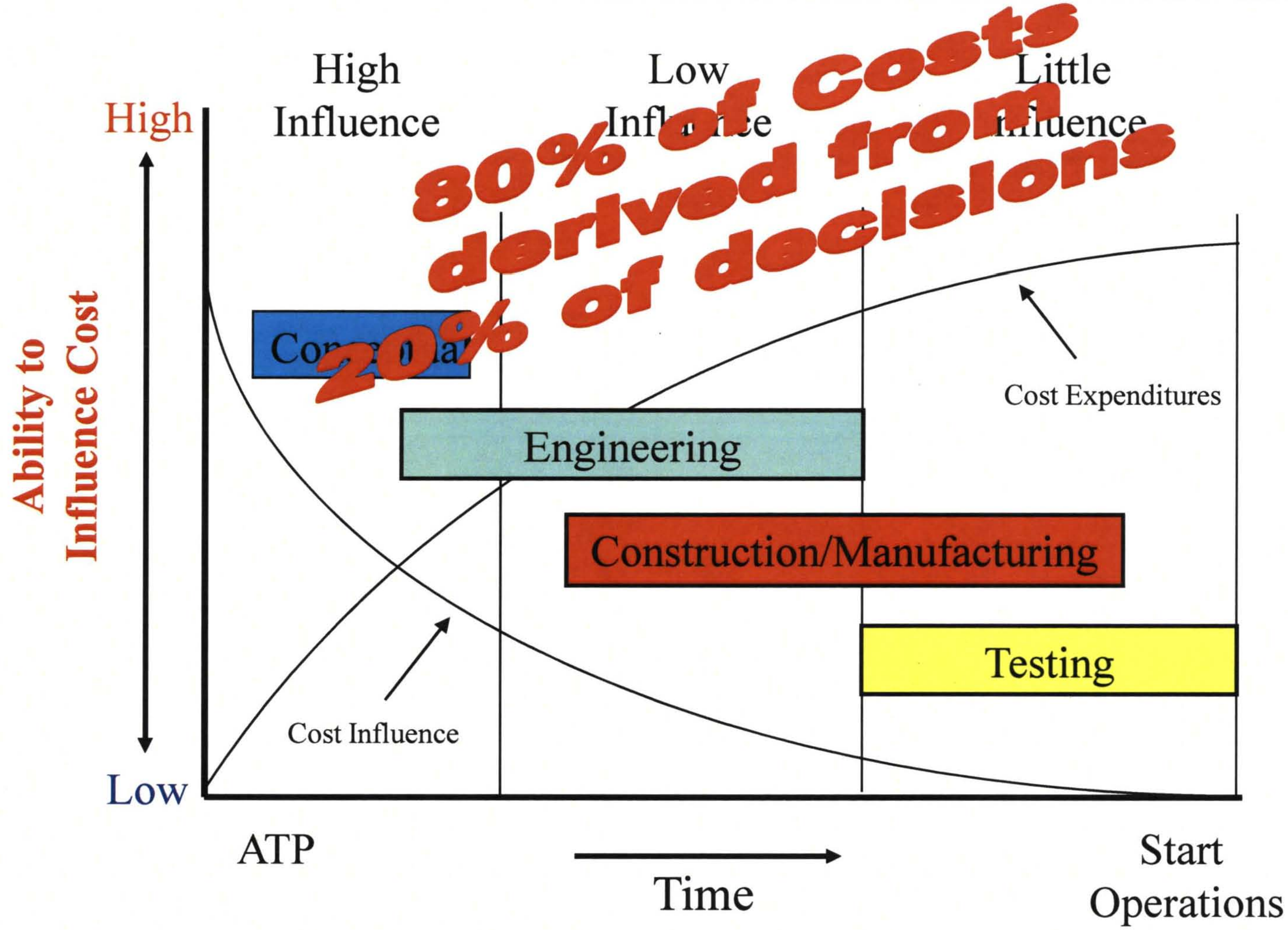
& Better Looking!

What is Good Enough?

- **Common for engineers to "gold plate" specifications**
  - They want a perfect system – This is safe
- **Example we built a 2,400 SF (223 SM) storage facility**
  - Engineers specified $18,000 electric panel when a $480 panel is more than adequate
  - **This is not a critical facility – Its for boat storage**



Early Design Choices
Affect Ability to Influence Costs



Rule of Thumb - The earlier a decision/change is made the lower the impact will be to schedule and budget and money

Avoid Change Orders!
Based on review of 5,000 change orders
Changes typically 25%–50% more costly than if incorporated early
Change Order
YAMAHA
40
Original Contract

Top Reasons Reality Exceeds Initial Projections

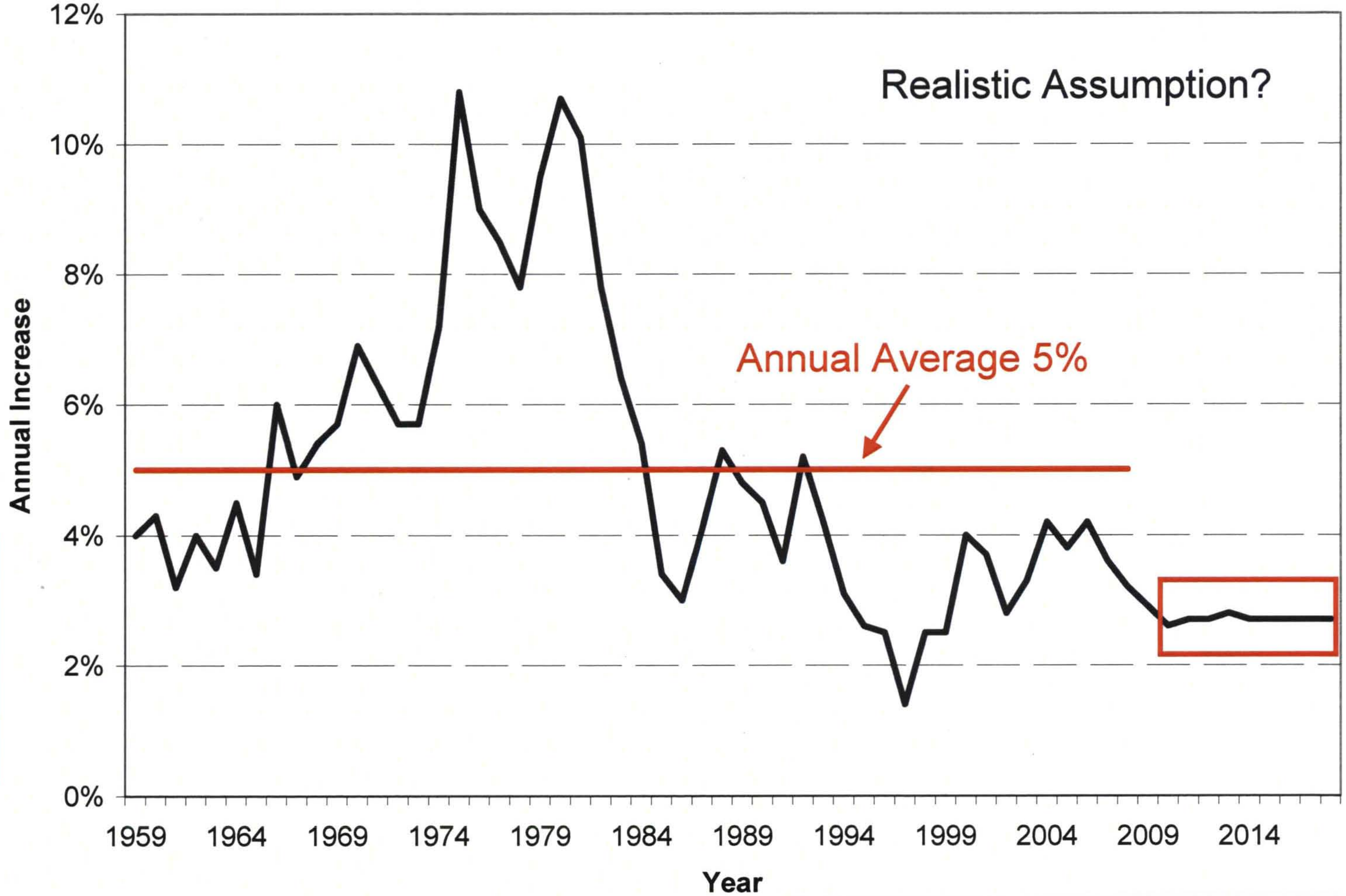
- **Planning Stage**
  - Budget is $100M so estimate has to be $100M or less
    - **Often driver of other issues**
    - Belief problems will be easily overcome
  - **Optimistic Assumptions**
    - Money will show up on time
    - We can use previous design from another project "as is"
    - Escalation will be low
  - Lack of accountability
    - Historically no real repercussions for overrun, but rewards for starting
    - Desire for perfection
  - We have to "hurry up" and award contracts to meet schedule
    - Initial schedule often politically set
  - Lack of adequate upfront planning
    - True requirements not clearly defined
    - Risks not identified
  - Insufficient contingency

- **Implementation Stage**
  - Deny existence of any problems as long as possible
  - Initial emphasis often placed on schedule
    - Drives shortcuts
  - Scope changes
    - "Desirements" creep in
  - Change orders required
    - Initial assumptions were optimistic & incorrect
    - Project not adequately planned due to schedule pressure
    - Zero cost change orders
  - Funding doesn't show up on time, or is cut
    - Big problem on international projects
  - Unintended consequences
    - the ripple effect
  - Lack of cost and schedule controls

Ignore/Influence Independent estimates

Escalation Assumptions Should be Realistic
NASA New Start Escalation Index

Rand - 1981 escalation accounts for 11.2% of project cost growth



88% probability assumed escalation will be exceeded

*"The current efforts to help revive the economy are **likely to produce inflation** that could be worse than what the country suffered in the late 1970s."*

Warren Buffett, March 2009

The Cost Of Change
Nothing is Free

- Every document, change, report, study, review, test, analysis, conference, telephone call, etc., has a cost in manpower & material. **All too frequently managers will delude themselves into thinking an action has "no cost" or "no impact"** when the true assessment would be that the action can be undertaken with a relatively small effort. Also, decisions to change an item are frequently made without a thought-out assessment of all aspects of the task & with only an assessment of the visible work involved.
- For example, when workshop was in the final stages of preparation, **a number of decals (containing operating instructions) were judged to be less clear than was possible.** When the final bill was known, **each decal change cost tens of thousands of dollars, all accountable**.** The visible task, removal of the old decal, the preparation & installation of the new, was only a few dollars, as you would suspect. However, good aerospace procedures were used & work orders had to be prepared & processed, the work had to be reviewed & inspected, the drawings had to be changed, the change had to be processed, drawing lists had to be modified, test procedures modified & reviewed, crew checklists had to be changed, & to all this, overhead costs had to be added.
- **Changing options, may reduce cost, but a price must be paid for everything.**
  - SKYLAB LESSONS LEARNED AS APPLICABLE TO A LARGE SPACE STATION, A dissertation submitted to the faculty of The School of Engineering & Architecture Of the Catholic University of America For the Degree Doctor of Engineering by William C. Schneider, Washington, D.C., 1976.

**Sticker changes cost in excess of 100K each in FY11 $

Don't Assume All Contractors Are Honest

Northrop Settles False Claims Case

Northrop Grumman Corp. has **agreed to pay $12.5 million to federal government to settle allegations that it submitted false claims** to government agencies in connection with electronic parts it supplied for navigation systems for military airplanes, helicopters and submarines.

Northrop's accused **of failing to test commercial-grade electronic components to ensure they would function at extreme temperatures required for military & space uses**.

- **Number of DOD actions for contracting fraud FY01-FY10**
  - SAIC 139,331
  - Lockheed Martin 119,499
  - Northrop Grumman 99,454
  - Raytheon 76,515
  - General Dynamics 68,339
  - Boeing 51,856 Actions
  - Honeywell 55,078

"Rogue Contractors"

- **Pentagon Paid $998,798 to Ship Two 19-Cent Washers**
  - 2007 - Small South Carolina parts supplier collected ~$20.5 million over six years for fraudulent shipping costs, including
    - $998,798 to ship two 19-cent washers to Fort Bliss (Army base in Texas)
    - $455,009 to ship three machine screws costing $1.31 ea. to Habbaniyah, Iraq
    - **$293,451 to ship 89-cent split washer to Patrick Air Force Base, Florida**
  - Exploited flaw in automated DOD purchasing system:
    - Shipping bills to combat areas or U.S. bases labeled "priority" usually paid automatically
  - C&D & 2 of its officials barred in December from receiving federal contracts
    - Charlene Corley, 46, was fined $750,000.
    - Faces maximum prison sentence of 20 years on each count
  - Fraudulent billing started in 2000
    - Started small & got more aggressive over time when invoices not questioned
    - **Purchase price** of items rarely reached $100 & totaled ~$68,000 over six years
    - **Total shipping charges** paid were $20.5 million
  - Scheme Detected
    - In September after purchasing agent noticed $969,000 bill for shipping two 19-cent washers

Confirmation Bias

- **Philosopher Francis Bacon in 1620**
  - *"the human understanding, once it has adopted an opinion, collects any instances that confirm it, & **though the contrary instances may be more numerous & more weighty, it either does not notice them or else rejects them, in order that this opinion will remain unshaken**"*
- **People have an unjustified bias in favor of *<u>their opinion</u>***
  - Much tougher when critiquing validity of information that undercuts one of their currently held theories than they are in supporting information that apparently endorses one of their own tenets.
  - Employing this double standard, tend to dismiss information that doesn't fit with what they already believe.

Stating the Obvious

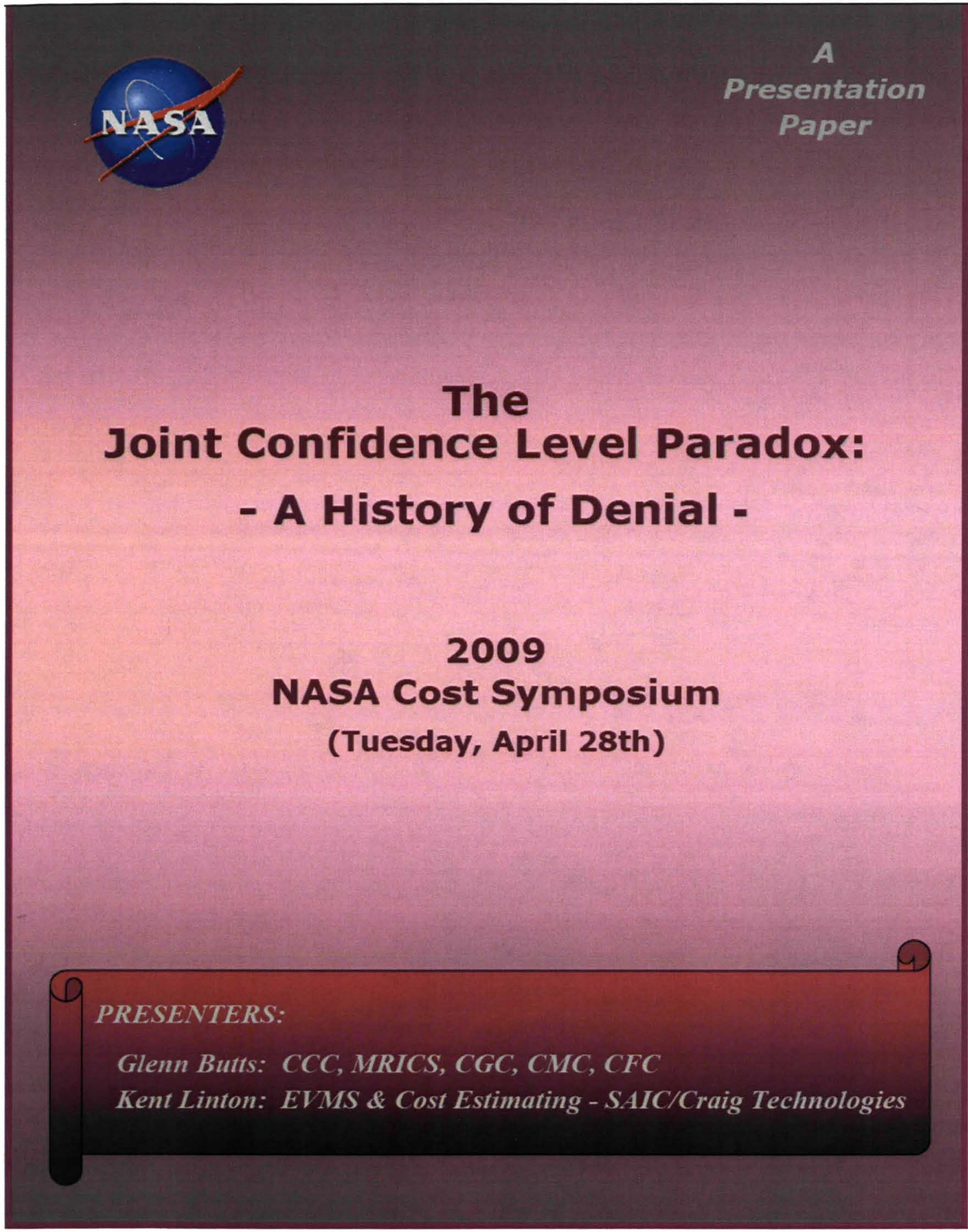
- **Estimates only as good as inputs provided**
  - In 2008 MIT surveyed 80 systems engineers
    - They were asked a series of questions that included
      - How many countries have McDonalds?
      - What is range of a Minuteman Missile in miles?
      - How long in minutes & seconds is song Stop in the Name of Love?
      - How many rulers has England had in the last 1,000 years?
      - How tall is Sears Tower in meters?
    - Asked large enough range to provide 90% certainty answer correct
      - Example - I am 90% sure that there are between 50 & 150 countries with McDonalds
    - 83% of Systems Engineers got 50% or less answers correct.
      - Worse in 221 times experts said they were 100% sure, only correct only 73% of the time
  - 1999 study of 27,000 expert predictions - did not vindicate their "expertness" as anticipated.
      - Error rates many times what experts predicted.
      - No advantage for experts holding advanced degrees.
- **Why is this important?**
  - If a system engineer tells you they are 90% certain about something - They will be WRONG much of the time!!
  - Base as many inputs as possible on objective data – not opinions

"In god we trust; all others must bring data" **Edward Deming**

Conclusions

- **Presentation probably not what you expected**
  - Before you can get help you have to admit there is a problem
- **My crystal ball says there is a high probability that SKA will overrun current cost and schedule budgets**
- **I strongly suggest that project**
  - Build in options that can be easily cut, or done later, when problems arise
  - Do one or more independent assessments that are ***truly independent***
  - Have strong project management team with business background

Backup


A Presentation Paper

The Joint Confidence Level Paradox:

- A History of Denial -

2009
NASA Cost Symposium
(Tuesday, April 28th)

PRESENTERS:

Glenn Butts: CCC, MRICS, CGC, CMC, CFC
Kent Linton: EVMS & Cost Estimating - SAIC/Craig Technologies

- **If you are interested in this topic, I wrote a 100 page paper on the subject**
- **Email me for copy**
  - Glenn.C.Butts@nasa.gov

We Claim to Seek Accurate Estimates

- **Yet, we;**
  - Persist in submitting optimistic initial estimates
  - Omit probable scope from our estimates that often become "real."
  - Exclude credible risks from our analysis
    - SM&A actively mitigates risks with a likelihood of occurrence of only one in several thousand, & are supported by management.
- **Management mantra**
  - “if status quo is assumed, we will get the status quo”
    - Meaning status quo is too expensive
    - There are valid reasons for why things cost what they cost
    - Excuse for under-estimating projects
- **Possible conclusions:**
  - **Accurate estimates are impossible, especially at early stages**
    - The variables are too complex, unquantifiable, & incalculable - NOT
  - **We really don’t want accurate estimates;**
    - Primary concern is keeping program viable & funded as long as possible
    - **Early estimates are deliberately misrepresented & meant to gain approval**

How Do We Underestimate?

- Let Me Count The Ways -

1. **OMIT PROBABLE SCOPE from estimate**
2. **OMIT POSSIBLE RISKS from analysis**
   - Internal & External
3. **UNREALISTIC, OPTIMISTIC assumptions**

Rand Study – Reason for 74% of Cost Growth

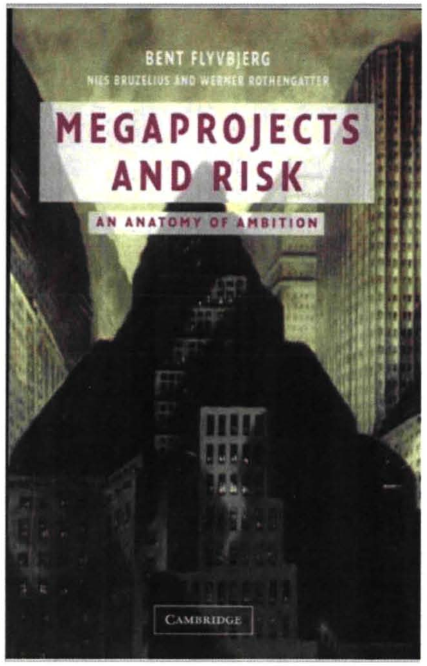
4. **Use historically LOW ESCALATION projections**
   - Rand Study – Reason for 11.2% of Cost Growth
5. **Issue cost estimates in BASE YEAR dollars**
   - Estimates should be in then year dollars (escalated to year in which it is spent)
6. **Many estimates NOT PREPARED BY A BONA FIDE ESTIMATOR**
   - Everyone's a estimator
   - Being certified no guarantee of having necessary experience
7. **REWARD failure, PUNISH honesty**
   - In my opinion many managers don't want good estimates
8. **NOT ENOUGH TIME to prepare CREDIBLE estimates**
   - Time often spent doing "what if" exercises, or splitting dollars into arbitrary buckets
   - Spend more time in reviews & defending estimates than preparing them

"I reject a system that rewards failure & protects a person from its consequences"

- Barack Obama -

Early Estimates are Often ***Deliberate*** Misrepresentation
Polite way of Saying Lying…….

- **Conclusions from the largest study of its kind:**
  - Examined 258 large ***transportation projects***
  - Underestimation has not decreased during past 70 yrs.
  - It was found with overwhelming statistical significance that cost underestimation cannot be explained by error.
    - "Is best explained by strategic misrepresentation, namely lying, with a view to getting projects started."
  - Cost overruns of 50% to 100% in real terms are common.
    - Overruns above 100% are not uncommon.
  - Accuracy is gained at each successive stage of progress.
  - Promoters routinely ignore, hide, or otherwise leave out important project costs & risks in order to make total costs appear low.

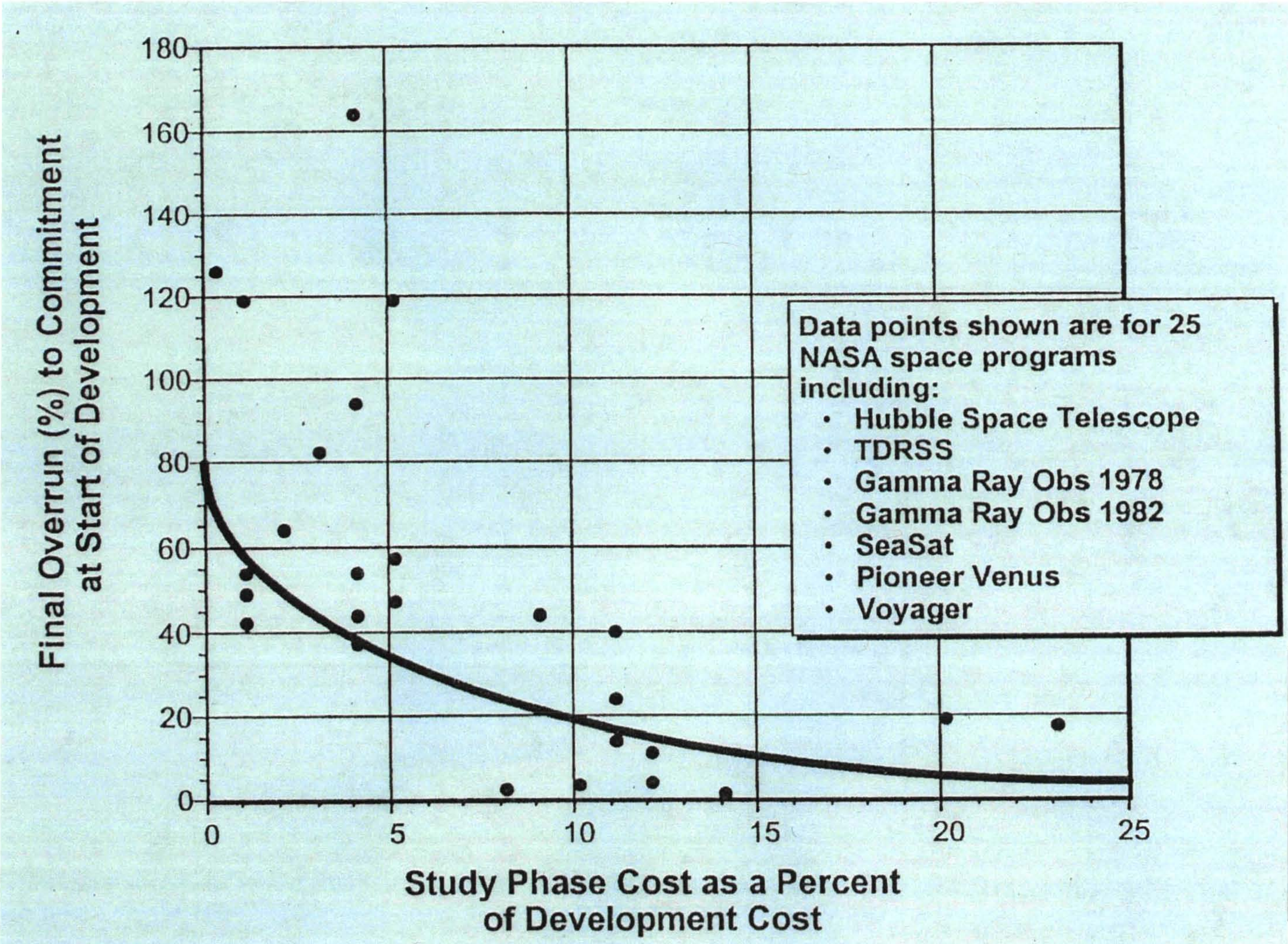


- Cost underestimation occurred in almost 9 out of 10 projects.
  - The likelihood of actual costs being larger than estimated is 86%
  - The likelihood of actual costs being lower than estimated is 14%

This study looked at comparatively simple projects.
Statistics for more complex projects would likely be worse!

Planning Stage

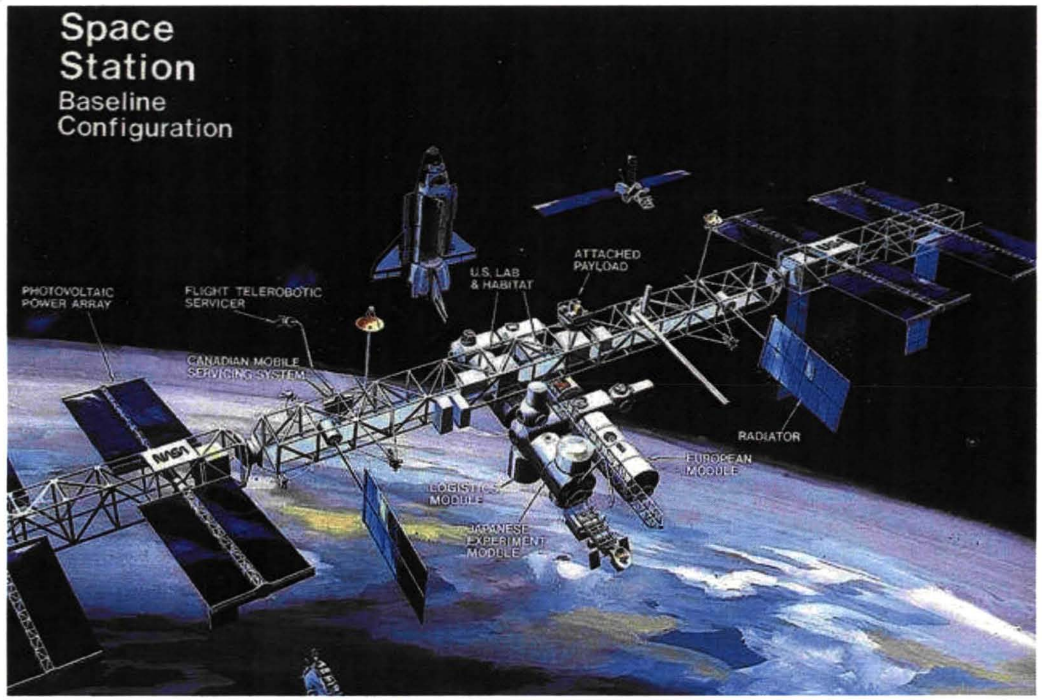
We don't adequately study project before we commit. Don't want to "waste" money on studies.



Spending More Money During Early Phase = Substantially Less Cost Growth

International Space Station

- 1984 President Reagan directed NASA to build a space station within a decade and to invite other countries to join the endeavor.
- 1991 the US House of Representatives held the **first of 22 separate votes on whether to proceed with the program.**
  - As a result of overruns it came within 1 vote of cancellation in 1993.
- **"For years the agencies cost overruns and schedule delays supplied ammunition for annual congressional attempts to kill the International Space Station"** – Florida Today



Multiple International Partners Adds Complexity

- **The more partners the more risk is added to the project.**
  - If one partner has difficulties it often has ripple affects
  - ESA's way of doing business is even less efficient than NASA's because they have the added complexity of making sure on any given project all 18 member nations puts in funding for a given project that matches their percentage "ownership" in ESA.
  - This can often make their contracting more difficult because they just can't let Company X in Country A do something that they are most efficient at and instead have to let the work be done by Company Y in Country B to keep the percentages correct.

International Partners

- **The ISS**
  - "The U.S. developmental effort cannot be isolated from these occurrences and their associated impacts: the Program has experienced cost growth and schedule slippage associated with this broad level of international involvement." Source http://history.nasa.gov/32999.pdf
  - Another ISS resource about international partner risks – see Appendix C, International Participation. From http://oig.nasa.gov/congressional/testimony040401.doc
- **The ITER project**
  - "The expert panels identified a number of factors arising from significant changes in circumstances and the parameters of the work necessary and contributing to the increases of cost estimates between 2001 and 2008. The most important factors relate to: increased complexity of project integration in managing interfaces across seven ITER Parties (in 2001 only 3 Parties were foreseen to execute the project)" Source http://fire.pppl.gov/iter_europa_cost_050610.pdf
- **GAO report. From http://www.gao.gov/new.items/d09306sp.pdf**
  - "These partnerships go a long way to foster international cooperation in space, but they also put NASA projects in a vulnerable position when partners do not meet their obligations or run into technical obstacles they cannot easily overcome."
  - "Project officials also commented that Aquarius had changes to its baseline due to slips by its development partner, the CONAE, [Argentina] and that they believe the NASA contribution to this mission is on schedule for completion in March 2009. They added that the benefit of the international partnership, plus the groundbreaking information about the Earth's climate, out weigh the additional costs, which NASA has chosen to absorb within its budget.

Report to the Committee on Science, House of Representatives
May 2004

GAO-04-642 Report @ http//www.gao.gov/cgi-bin/getrpt?GAO-04-642

- **"Lack of Disciplined Cost-Estimating Processes Hinders Effective Program Management"**
  - NASA lacks clear understanding of programs cost & schedules.
    - Estimates for more than half of programs reviewed have increased—as much as 94 percent.
    - Cost Estimates increased 80% of time
    - Variability in cost estimates indicates ***programs lacked sufficient knowledge needed to establish priorities, quantify risks, & make informed investment decisions, & thus predict costs.***
- **"NASA's basic cost-estimating processes—an important tool for managing programs—lack discipline needed to ensure that estimates are reasonable."**
  - None of programs reviewed in detail met all cost-estimating criteria.
- **"NASA has limited ability to collect program cost & schedule data needed to meet basic cost-estimating criteria."**
  - **<u>NASA does not have a system to capture reliable financial & performance data—key to using effectively the cost-estimating tools that NASA officials state that programs employ</u>.**
- ***NASA identified other barriers, including limited cost-estimating staff.***

GAO Cost Estimating Criteria

1) Objectives of estimate shall be stated in writing.
2) Life cycle to which estimate applies is clearly defined.
3) Tasks appropriately sized.
4) Estimated cost & schedule are consistent with demonstrated accomplishments of other projects.
5) Written summary of parameter values & their rationales accompany estimate.
6) Assumptions shall be identified & explained.
7) Structured process such as a template or format shall be used to ensure that key factors are not overlooked.
8) Uncertainties in parameter values are identified & quantified.
9) If schedule is imposed, estimate for normal schedule shall be compared to additional cost required to meet imposed schedule.
10) If more than one estimating approach is used, variances are analyzed & explained.
11) Independent assessment concur with the values & methodology.
12) Estimates kept current.
13) Estimates integrated with project planning & tracking.
14) EVM is used to manage program.

Basically – Good Processes & Documentation

Underestimates are Nothing New - *Quotes from 1964*

All but One from Apollo Executives Meeting

- *"I can think of a lot of programs in the Boeing Company where, **if the estimate had been realistic, you wouldn't have had the program, & that is the truth."***

  W. M. Allen - President, Boeing

- ***"You have basically built into the entire system a series of events which very much leads to under-estimating what the program is going to cost."***

  J. S. Parker - Vice President, GE

- ***"As advocates of new programs, government agencies have often encouraged contractors to estimate costs optimistically.***
  - *Recognizing that headquarters might be shocked out of supporting a program where true costs were revealed at the outset.*
  - *They have sought to disclose cost increases gradually, after programs have gained momentum & cancellation has become difficult."*

  Dr. Frederic Scherer - Harvard

- ***"We can give you estimates all the way to the end of the Saturn-IVB, but do you really want to know it?"***

  Donald W Douglas - President Douglas Aircraft

Underestimates documented back to 1869 – probably prior.

Common Causes of Cost Problems

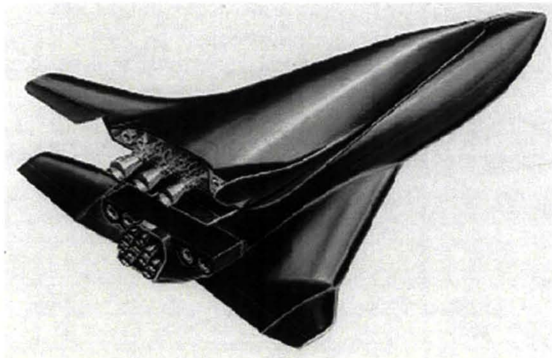
- Optimistic assumptions
- Poor estimating techniques/standards/processes
- Inadequate work breakdown structure
- Technology readiness
- Managerial edicts to reduce estimates by eliminating “fat”
- Inadequate planning that results in increased scope
- Requirements creep
- Unforeseen technical problems
- Schedule delays
- Inadequate workforce skill mix
- Contractor buy in
- Lack of historical data

Common Causes of Cost Overruns

- Failure to understand customer requirements
- Unrealistic assessment of current capabilities
- Underestimating time requirements
- Omissions (inadvertent or deliberate)
- Misinterpretation of information
- Inappropriate estimating techniques
- Failure to identify & concentrate on major cost elements
- Failure to recognize & <u>plan</u> for risks
  - Ignore external risks
- Pressure to compromise early
- Ceiling Costs
- Must win mentality (Success Oriented)
- Poorly written contractual requirements
- Proposal team <u>different</u> from Project team

Forgotten SPACE SHUTTLE Facts

- **Initially approved by 1 Vote**
  - Congress WAS concerned about estimates
- **FY 1972 Estimate**
  - DDT&E $5.5 Billion + 20% Contingency = $6.6 Billion
    - Contingency Reportedly Removed by Congress
  - Facilities $0.3 Billion
  - 1st Manned Flight projected by **June 1976** **(4 yrs.)**



- **Reality - 1982**
  - Total Cost $17.789 Billion
    - DDT&E $13.138 Billion
    - Production $ 3.900 Billion
    - **Facilities $ 0.703 Billion**
  - 1st Manned flight occurred in **April 1981** **(9 yrs.)**

"The chance of a Shuttle launch on November 20 1980 is probably 10 to 20%"

Dr. Frosch NASA - Administrator
Congressional Testimony 1980

- ***Increase WAS Foreseen . . .***
  - ***"Considering all of the technological & operational unknowns involved*** *in the shuttle development & the fact that no vehicles of similar function have ever been designed before or have ever operated over the range of flight regimes required for the shuttle, prudent extrapolation of prior experience would indicate that estimated development costs may be 30 to 50 percent on the low side. Thus, the estimates of $6.5 billion in RDT&E for the Mk I/Mk II shuttle program may range between $8.5 to $10 billion, reflecting increased program costs of $2.5 to $3.5 billion. Similar uncertainties must be considered to apply to other non-recurring costs such as production & facilities (amounting to about $4 billion). Thus a possible cost uncertainty of about $5 billion for total program costs might be envisioned giving* ***a high estimate of total non-recurring cost of about $15 billion."*** ***- October 1971 Report -***

Were to Start? – Elements That Influence Costs

- **What – is project scope?**
  - What are boundaries of work
  - Who will do required work outside boundaries?
- **Who – will do**
  - **Design?**
    - Self
    - On call A&E
    - New A&E
    - On board Support contractors
      - Self perform work
      - Sub out
  - **Work? – FFP or Cost Plus**
    - On board support contractors
      - Self perform work
      - Sub out
    - General Contractor
    - General Contractor & Sub Contractor's
- **How – will project be bid?**
  - Full & open
  - Source board
  - IDIQ
  - Sole source
    - 8a - Disadvantaged
    - Support contractor
    - Other
  - Best value
  - Design build
  - Cost plus
- **Where – will project be done**
  - On center
  - Off center
    - Costs may change with location change
- **When – will the project be done**
  - Required for escalation calculations
  - Anticipated market conditions
    - Negative or positive

Point

Details Matter!

Backup
Misc Projects Lessons Learned

CLCS Summary - Lessons Learned
$400 M Software Project

Huge Overruns Project Canceled

1. Independent Project Oversight
   - Vigorous independent review process critical to ensure early warning to senior management.
     - Senior management must follow-up on independent reviews & control performance
2. Control Project Requirements
   - Control requirements early & ensure understanding of them between stakeholders
   - Must be placed under configuration control – with no changes unless through analysis is done
     - Any changes must be carefully balanced by cost, development & operational risks
3. Risk Management Mitigation
   - Clear identification of each significant risk, their probability of occurrence, impact of risks on project, & clear plan for risk mitigation are critical to project success
   - Cultural impediment to implementation are significant and must be overcome
   - Implement periodic validation of risk assessment by group external to the project
4. System Integration & Performance Management
   - Implement an effective Systems Engineering group to be responsible & accountable for systems design, integration, performance analysis & verification
   - Lack of early planning manifests itself in cost overruns, failed acceptance testing, slipped schedules, and disruption of planned integration of interfacing systems.
5. Milestones
   - Project milestones must explicitly defines what capabilities are included in each
6. Communications
   - Project managers must focus on meeting approved requirements while controlling cost & schedule.
   - Communication, requirement definition & integration should be prime management metric.
7. Estimating
   - Sound cost & schedule estimating early, including a bottoms-up cost estimate, coupled with use of accurate performance management system is essential to meeting project goals.
8. Contract Vehicle
   - Contracts should be structured such that performance on important work has an overall effect on performance award.
   - Caution should be utilized such that the conflict of interests are created

NASA continues to relearn lessons already learned from the past.

A3 Lessons Learned

- **Phased Funding**
  - Not delivered when promised
    - Drove segmenting of bid packages
  - Budget cut
    - Have de-scope options planned ½ SKA?
- **Requirements**
  - Geographically separated teams maintain separate requirements documents
    - Drove Change Orders & Schedule slips
      - LOX barges pumps changed, new requirement for VFDs. Great impact to electrical power systems (requiring larger diameter wiring, conduit, etc). However, decision NOT coordinated with A-3 project.
  - All not available until design 30% complete – Impact cost and schedule
  - Concept, schedule & budget locked before all requirements known
    - Initial concept did **NOT** include plans for buildings to house electronic equipment required for facility control & capturing test data.
    - Planned availability dates for **necessary** buildings not incorporated into overall project schedule making it extremely difficult to plan for installation, verification, and activation tasks
  - Not reviewed by ALL the necessary stakeholders
  - All "rated" equally – some critical, some are not – all could not be met
    - Vendors unaware of importance did not meet some requirements with proposals
  - Project data maintained on three different database systems
    - Everyone does not have access to all systems, so data duplicated & not always updated

A3 Lessons Learned

- **Design changes**
  - Result of review comments and resulting in scope growth/cost growth
  - Design schedule difficult to maintain with changing scope
  - Cryogenic tanks resized due to high bids – driven by transportation costs
    - Drove changes to other systems
    - Original size tanks could have been shipped by barges, not investigated
  - Design errors / conflicting data
    - Driven in part by schedule, in part by late stage design changes
- **Rush to maintain schedule/budget**
  - Required contract awards before design complete – caused cost of some contracts to double
  - Defer factory work to field, where skills not always available to perform
  - Company who will install items did not order them
    - When they arrived late, installation contractor got change order
    - Another company responsible for transportation
  - Preliminary System Hazard Analysis was not performed in concept phase
    - Drove later changes to mitigate hazards
  - Short timeline on requests for budget / schedule actions
    - Does not provide sufficient time to properly evaluate requirements & formulate plan
      - Example - request to provide estimate for Low Speed Video System in one day
      - Subsequent costs were higher, and additional funding difficult to obtain

A3 Lessons Learned

- **Bureaucracy**
  - Nine months to order equipment, delivery only took 6-8 weeks after order finally placed
    - This occurred on small orders $150K & less
    - Small contracts should be treated differently than big ones
  - Excessive regular meetings that project consume time which could be applied to productive work
    - Three to six meetings a week in various forums, does not allow sufficient time to perform project actions
  - Failure to utilizing remote meeting capability effectively
    - It good to have face-to-face meetings yet as a project progresses, travel times for meetings can impact delivery schedules
    - Use of internet format meetings allows sharing of technical documents with minimal interruptions to productive work
  - Regulations on contract value limits drove splitting of bid packages into small packages
    - Increased confusion
    - Increase coordination work on project team
- **Risks**
  - Optimistic initial estimates by people with vested interest in gaining project approval
  - Failure to accept independent cost assessment
    - Exerted pressure to force retraction and agreement with projects number
  - Hurricane Katarina
    - Due to rebuilding efforts costs were substantially higher than estimated
- **Other**
  - Coordination of multiple contracts on scope & availability sometimes a problem
    - If project was one large fixed price contract you know who has scope
      - Items in design don't get lost in the shuffle

Lessons Learned

- **Project Formulation**
  - Watch out for unrealistic cost and schedule estimates resulting from:
    - Inaccurate/incomplete understanding of requirements for spaceflight end items
    - "low balling" in order to get an ATP
    - an overrating of the technology maturity
- **Procurement**
  - Never agree to a cost plus fixed fee contract for a research, design and development effort
    - The contractor bears no risk -- it's all on the government
    - The government has no leverage with the contractor -- no incentives (positive or negative) for addressing problems

Lessons Learned

- **Project management**
  - Contractor Project Manager should have a proven track record (deliveries, communications, risk management)
  - Don't skimp on oversight functions -- match each major contract skill/function with an accountable government counterpart
  - You must have reliable, accurate, and timely cost reporting
  - Pay close attention to environments:
  - Perform functional testing in relevant environment to the extent possible
  - For situations you can't thoroughly test for, do "what if" study to find possible effects and solutions
  - Don't ignore quirky test data -- it may be telling you something important
  - Develop back up plans for all reasonably possible contingencies
  - Conduct comprehensive failure or anomaly investigations
  - Take whatever action is necessary to control the contractor -- be prepared to descope or terminate
  - Take risks for good reasons and with management's buy-in
  - Trust dedicated, "can do" team members to come up with creative solutions to issues